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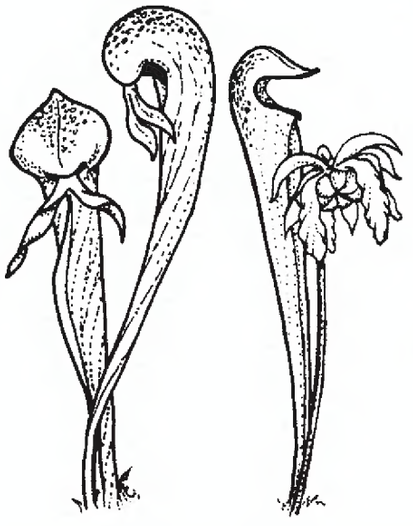

CARNIVOROUS PLANT NEWSLETTER

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Front Cover: The splash-cup in action. A single water drop distributes gemmae from the center of a *Drosera pulchella*. Photo by Greg Bourke. Article on page 52.

Back Cover: *Drosera gibsonii* at Buff Knoll, *D. micrantha* at Muchea, and *D. leucostigma* at Regans Ford, all in Western Australia. Photos by Richard Nunn. Article on page 52.

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Splash-cups, springboards, and sink or swim – Preliminary study of the strategies for vegetative propagule dispersal in Pygmy *Drosera*

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Keywords: Droseraceae, carnivorous plants, *Drosera* section *Bryastrum*, pygmy sundews, dispersal, Australian flora.

Abstract: The *Drosera* of the subgenus *Bryastrum*, commonly referred to as pygmy sundews are unique to the genus in that all bar one produce vegetative clonal propagules known as gemmae. These gemmae are thought to be dispersed via a novel adaptation known as a splash-cup, but little is known about its effectiveness or other strategies employed by the plants. In this preliminary study, the splash-cup was tested and its effectiveness measured. The role of the stipules, which form the walls of the splash-cup were also examined along with other features of the plants' architecture. The splash-cup was found to play a critical role in gemmae dispersal while the theory that the stipules perform as spring-loaded catapults was unsupported. Additionally, gemmae were found to either sink or float depending on the taxon. Observational evidence is provided which suggests the structure of a gemma plays a significant role in the success of each taxon in its preferred habitat.

Introduction

Drosera L. subgenus *Ergaleium* sect. *Bryastrum* Planchon is a group of carnivorous plants commonly referred to as pygmy sundews. All bar one, *Drosera meristocaulis* of South America (Rivadavia *et al*. 2012) are characterised by their unusual strategy of vegetative propagation through the production of gemmae. With the onset of cooler temperatures, they produce small, hard clusters of modified leaves (gemmae) atop short translucent stalks (Lloyd 1942; Lowrie 1989; Lowrie 2013). Each gemma is attached to its own stalk via just a few cells (Fig. 1) and as it matures, this junction becomes tenuous and is easily broken with the slightest disturbance (pers. obs.). If undisturbed, eventually the gemma's connection is severed by the plant at the cellular level.

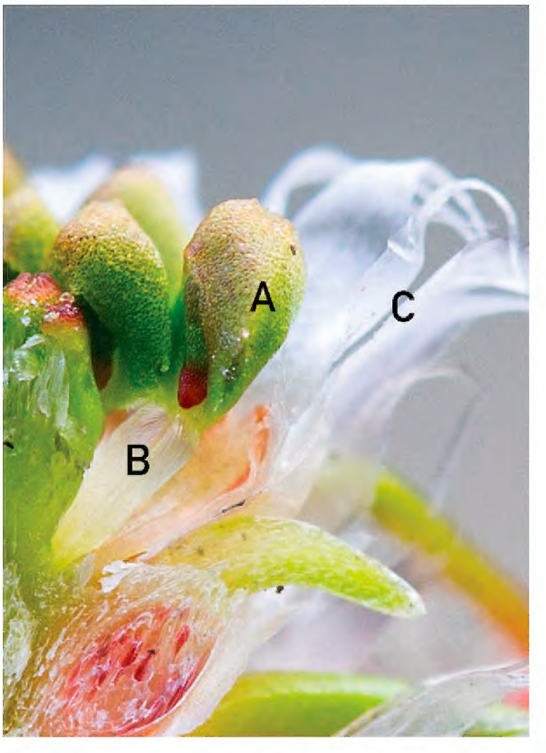

Figure 1: *Drosera scorpioides*. (A) developing gemma, (B) stalk, (C) stipules forming the wall of the splash-cup.

Under natural conditions gemmae are dispersed from the parent plant by disturbance (pers. obs.). It is broadly accepted that this process of gemmae distribution is through a novel rain dispersal mechanism known as a splash-cup (Lloyd 1942; Lowrie 1989; Lowrie 2013). This method of propagule dispersal is

well documented from Birds Nest Fungi (Nidulariaceae) and several mosses and liverworts (Brodie 1975). However, a number of plants including *Sedum* spp., *Gentiana* spp., *Veronica* spp. (Nakanishi 2003) and at least three other sundews, *D. felix*, *D. kaieteurensis*, and *D. solaris* (Fleischmann *et al.* 2007) employ this strategy to disperse seeds.

Additional to the splash-cup method, at least one author has suggested the highly developed stipules that form the walls of the splash-cup play a secondary role in gemmae dispersal (Lowrie 1989; Lowrie 2013). Lowrie has hypothesized that the stipules place the developing gemmae under considerable tension (spring force), eventually forcibly dispersing the gemmae when disturbed (Lowrie 1989; Lowrie 2013).

Observations in the field and of cultivated plants by the author suggest gemmae dispersal is affected by a number of factors and is not limited to initial dispersal from the plant. The structure of the gemmae themselves contributes further to dispersal once dislodged from the plant and prior to rooting. Experiments were conducted between 2018 and 2020 under controlled conditions to investigate some of the factors may which may affect gemmae dispersal. These included:

- The splash-cup - dispersal by raindrops
- Springboards - dispersal via stipule spring force
- Sink or swim - secondary dispersal by water

Materials and methods

The splash-cup - dispersal by raindrops

The splash-cup is a specialised adaptation employed by some organisms to disperse propagules and in pygmy *Drosera*, a seemingly critical adaptation given the resources used in the process. In some species, at the time gemmae are produced, they may represent as much as 30% of the biomass of the plant (pers. obs.). In autumn, vegetative propagules grow in the centre of the rosette, surrounded by a number of overlapping stipules. These stipules form the splash-cup and as each gemma matures, it is easily dislodged by disturbance such as rain which, when striking the splash-cup, can carry the gemma some distance from the plant (Fig. 2; front cover). It has been suggested this can carry the gemma as far as 2 m (Lowrie 1989; Lowrie 2013).

As gemmae are produced in the centre of the plant's rosette, the stipules are forced outward. When the first gemmae mature, the stipule cup can vary in shape and size depending on the species, from cupuliform to cyanthiform, with stipule angle commonly between 0° and 30° from vertical (pers. obs.). In some species, gemmae production

Figure 2: The splash-cup in action. A single water drop distributes gemmae from the centre of a *Drosera pulchella*.

continues throughout autumn (e.g., *D. pulchella*) while others only produce one cluster (e.g., *D. miniata*) each autumn (A. Fleischmann pers. comm.). As gemmae mature, this angle increases and as the last few gemmae mature, the stipule cup may become crateriform approaching 60° from vertical. Experiments by Amador *et al.* (2013) found that the optimal cone angle for a splash-cup is 40°, and all pygmy *Drosera* observed by the author produce splash-cups of this angle during the production of gemmae. Amador *et al.* (2013) also found that to achieve the greatest dispersal distance, an off-centre raindrop strike is required. In fact, laboratory experiments demonstrated that an off-centre strike results in an acceleration of the raindrop in a model splash-cup (Amador *et al.* 2013).

In order to test this, live plants of *D. scorpioides* and *D. pulchella* were selected. A single water droplet of 5 mm (+/- 10%) diameter was used to simulate a large raindrop. This size is considered to be near the upper limit of falling water drops (Van Boxel 1997). The droplet size was obtained using a 1 litre water vessel fitted with a 3 mm gate valve, trimmed to achieve a consistent droplet size and droplets weighed to confirm size. The droplet was released from a height of 4 m above the splash-cup. At this height, approximately 80% terminal velocity was achieved and a speed of approximately 8 m/s (calculated using Van Boxel's rainfall simulator) (Van Boxel 1997).

Each plant was placed in the target area and aligned to achieve an off-centre strike. All gemmae were removed from the rosette centre of the plant and then 10 loose gemmae were placed in the splash-cup. A single water drop was released and distance and distribution of gemmae measured and mapped. This was repeated four times for each of the two *Drosera* species.

Springboards - dispersal via stipule spring force

To test the theory of stipules dispersing gemmae via spring forces, plants of *D. scorpioides*, *D. pycnoblasta*, *D. pygmaea*, and *D. pulchella* were cultivated in a controlled environment. The species selected represent extremes of growth form for the subgenus, i.e., *D. scorpioides* con-

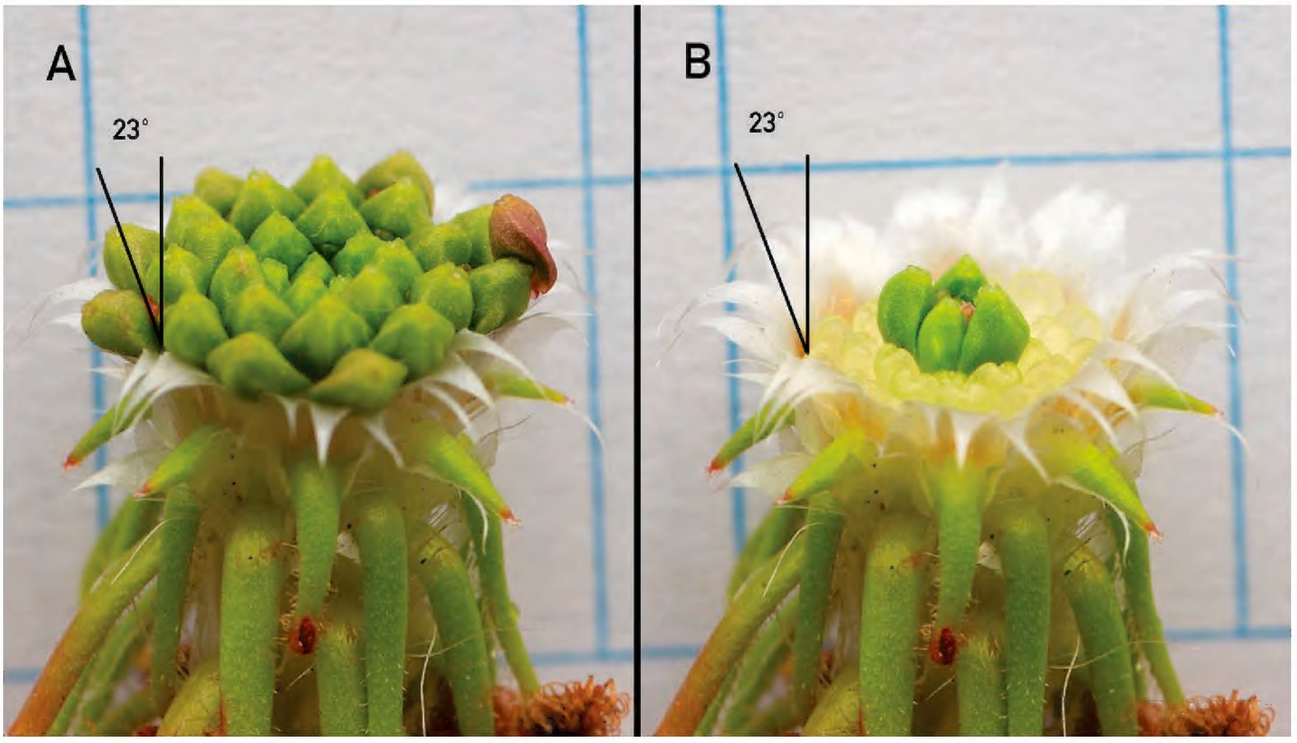

Figure 3: (A) *Drosera scorpioides* packed with gemmae and (B) with gemmae removed. The angle of the splash-cup wall is shown.

sidered the tallest, *D. pulchella* and *D. pygmaea* being flat rosettes (largest and smallest among the sampled species), and *D. pycnoblasta* somewhat intermediate in habit. Two groups of plants were monitored. Both groups were allowed to produce gemmae as they would naturally but with no disturbance from overhead watering or any other disturbance forces. At the point where gemmae matured to the stage of naturally disconnecting from the parent plant, one group had its gemmae removed and angle of deflection measured using vernier callipers with one, *D. scorpioides* photographed against a 1 cm grid (Fig. 3). The second group were left to further mature with gemmae behaviour recorded.

Sink or Swim - secondary dispersal by water

In the wild, pygmy *Drosera* can be found in a range of habitats from margins of lakes to rocky hillsides in various substrates (pers. obs.; Bourke & Nunn 2012; Lowrie 2013). Around lake margins, pygmy *Drosera* can be found in large numbers, often concentrated along the winter high water mark (pers. obs.; Lowrie 2013). This suggests that conditions along the water's edge are ideal from gemmae establishment, that that water may play a role in the distribution of gemmae, or that gemmae that fall outside this zone perish in less than ideal conditions.

Heavy loam soils with laterite form a common substrate for many pygmy *Drosera* also, and during late autumn when rain is often heavy, water flows across the surface, washing nutrients, debris, and potentially gemmae away. Yet many pygmy *Drosera* species thrive in these substrates, often on steep gradients, seemingly losing few gemmae to the erosive forces of rain.

To date, there has been little documented as to how and why pygmy *Drosera* are distributed in such habitats with the implied theory that the plants produce many gemmae relying on luck that some will persist in where and when conditions are favourable. Observations by the author suggests that the gemma shape, surface architecture, and density may play a role in ensuring success.

To test dispersal via water, 30 gemmae of a number of different taxa were dropped from a height of 5 cm into a 75 ml jar with 50 ml of rain water. The number of floating vs sunken gemmae was recorded. A lid was then placed on the vessel and it was agitated vigorously for 10 seconds. The number of floating vs sunken gemmae was once again recorded. This was tabled against the habitat and soil type from which the plants were sourced.

Results and discussion

The splash-cup - dispersal by raindrops

The splash-cups were effective in dispersing gemmae but the distances achieved were low. With *D. scorpioides*, a maximum distance of 73 cm was achieved with just 20% exceeding 50 cm while almost 70% travelled under 10 cm. *Drosera pulchella* achieved less impressive results with the furthest gemma at 35 cm (Fig. 4).

The stiff, erect stems of *D. scorpioides* deflected and sprung back dramatically when struck with a water droplet. The review of video footage suggests that it may actually have a detrimental effect on dispersal as the deflection of the stem consumes energy from striking droplet. This small energy loss may be a trade-off for ensuring the splash-cup is positioned above the often-rocky substrate. In the wild, plants often occur in dense populations, providing support for each other which could remove some of this deflection when struck.

The angle of the splash-cup walls changes over time and between species (pers. obs.). Further experiments are required for a broader range of species and at different stages of development in order to gain a better understanding of the effectiveness and of the splash-cup.

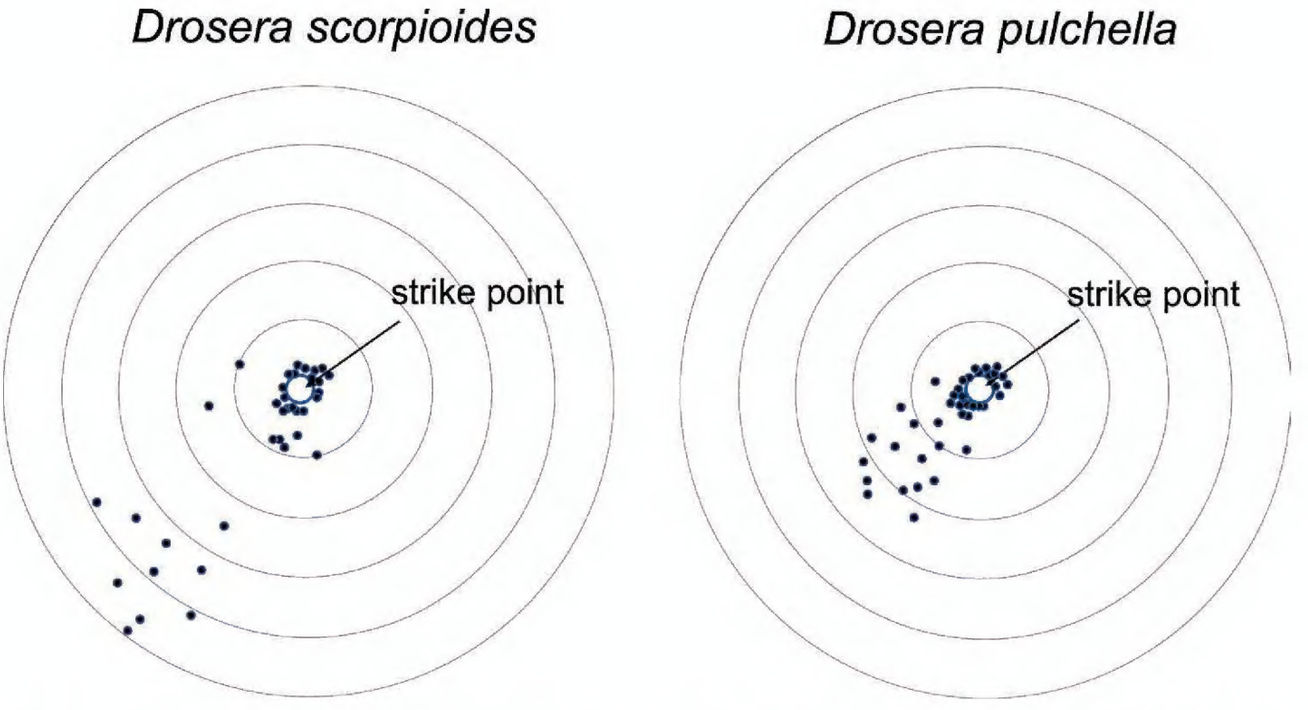

Figure 4: Location and orientation of dispersed gemmae following an off-centre water droplet strike. The centre circle represents the splash-cup with thin concentric circles representing 15 cm increments.

Springboards - dispersal via stipule spring force

According to Lowrie (2013), as gemmae mature, they place the stipules which form the walls of the splash-cup under tension and any disturbance such as that from a raindrop, will cause the cluster of gemmae to explode, being forcibly evacuated from the plant. Unfortunately, the process outlined by Lowrie was not able to be replicated in this study. With *D. pulchella*, as gemmae matured and were severed by the plant, they were simply pushed upward by the developing gemmae below, bound by the walls of the splash-cup (Fig. 5 Left). In *D. pycnoblasta* and *D. scorpioides*, the mature gemmae simply commenced leaf and root development whilst more or less remaining in position within the splash-cup (Fig. 5 Right).

In the second group of plants, removal of gemmae from a full splash cup resulted in no deflection of the stipules (Fig. 3). It appears that the petiole bases from which the gemmae develop are what force the stipules apart. However, gemmae placed against the wall of stipules could be dispersed some distance by pushing the stipule outwards with tweezers and then releasing the applied spring tension.

Further investigation is required to determine whether Lowrie's observation is a rare occurrence or whether it occurs in some, but not all taxa.

Sink or swim - secondary dispersal by water

The results of the 21 taxa tested are provided in table 1. Of the taxa tested, those associated with laterite/gravel soils on sloping ground, 62% of gemmae sunk when dropped into water. This figure rose to over 90% when agitated. As for species associated with swamps and lakes, just 9% sunk when dropped into water while 31% sunk when agitated.

Four taxa were excluded from these calculations. *Drosera echinoblastus* and *D. mannii* inhabit the margins of streams as well as heath and woodlands, while *D. helodes* and *D. micrantha* inhabit fairly open heath in flat, low lying areas. It is the opinion of the author that whether the gemmae of these taxa float or sink probably doesn't play a significant role in their success but further investigation may be useful.

Figure 5: Left: *Drosera pulchella* left undisturbed with gemmae piling up. Right: *Drosera pycnoblasta* left undisturbed with sprouting gemmae.

Interestingly, the two *D. scorpioides* samples from contrasting habitats provided clear and opposing results with 100% of those originating from laterite soils sinking while 0% of those originating from swampy habitat sunk. This is consistent with other taxa from comparable habitat and soil types. As the material tested originated from cultivated plants, it is not possible that this is as a result of environmental factors and therefore must represent genetic variation. Further sampling is required of these taxa to better understand these taxa.

Conclusions

This preliminary study provides the first data from tests conducted in a controlled environment for pygmy *Drosera* gemmae dispersal. The splash-cup is an effective adaptation for distributing gemmae but the data did not support that found in some literature. Testing of a broader range of taxa is required to confirm just how successful the splash-cup is for gemmae dispersal in pygmy *Drosera*. The primary role of the stipules was found to be in the production of the wall of the splash-cup and the claim that spring tension plays a role in distribution of gemmae in an explosive event was unsupported. Stipules were found to provide a means of gemmae dispersal when disturbed and their role in gemmae dispersal requires further investigation.

Whilst the data provided good insight into the theory of secondary distribution of gemmae, the results of different *D. pygmaea* and *D. scorpioides* samples suggest broader sampling of a range of taxa is required to better understand this strategy and perhaps provide insight into the evolutionary adaptations developed by isolated populations.

Table 1. Results of testing the potential of secondary dispersal of 30 gemmae in water.

Taxon	No. sink when dropped	No. sink after agitation	Habitat	Soil type
D. closterostigma	21	28	winter wet depressions and swamps	pale sand
D. echinoblastus	27	30	margins of seasonally wet streams	pale sand
D. enodes	0	0	winter wet depression	peat based
D. gibsonii	30	30	sloping hillsides in heath	laterite/gravel
D. helodes	15	29	low lying areas	pale sand/laterite
D. lasiantha	26	30	sloping hillsides in heath and open woodland	laterite
D. leucostigma	0	10	winter wet depressions and swamps	pale sand and peat
D. mannii	0	15	watersheds and creek margins	peat or laterite
D. micrantha	28	30	flat open heath	pale sand
D. nitidula	0	18	seasonally flooded depressions and swamps	yellow sand with clay
D. occidentalis	0	1	margins of swamps	peat
D. patens	0	0	margins of swamps and lakes	pale sand
D. platystigma	0	21	flat to gently sloping hillsides in woodland	laterite
D. pulchella (Scott River)	0	10	margins of swamps	pale sand/peat
D. pulchella (Mt. Cooke)	0	10	seasonally inundated swamps	pale sand
D. pygmaea (Cox Scrub S.A.)	0	6	margins of swamps	black sand/peat
D. pygmaea (Kai Iwi Lake N.Z.)	10	20	margin of lake	pale sand/peat
D. scorpioides (Albany)	30	30	sloping hillsides in heath and open woodland	laterite
D. scorpioides (Marbleup)	0	0	seepage margin of swamp	pale sand/peat
D. stelliflora	0	26	flat to gently sloping hillsides in woodland	laterite
D. verrucata	26	26	sloping hillsides in heath	laterite

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Online Guide to the Pygmy *Drosera*

https://www.carnivorousplants.org/cp/taxonomy/pygmyDrosera

The ICPS public education website has a new online guide to the pygmy *Drosera* located in the About CPs/Taxonomy section. The guide is intended for use in identifying plants in cultivation as well as in the field. The pages adapt to screen size and work well with personal computers, tablets, and phones.

The guide includes short introductions to all 54 species and 6 taxonomically named hybrids. There are currently 332 images in the guide. The images were provided by Richard Nunn, Thilo Krueger, Manfred Meisterl, Steve Fretwell, Stewart McPherson, and John Brittnacher.

Drosera gibsonii. Photo by Thilo Krueger.

Can Venus flytraps be triggered to close by raindrops?

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Abstract: *Dionaea muscipula* traps, in a natural setting, are sometimes triggered to close without capturing prey. In the Florida panhandle, in dry weather, time-lapse photographs show the frequency of closure without capture to be 2.1 closures/% of active-traps/day. A sudden burst of intense rain can increase this by two to three orders of magnitude for a brief time. Frequencies of 15.5 closures/% of active-traps/hour and 148 closures/% of active-traps/hour have been measured. The large increase in closures occurs when rain first starts, because the most exposed and most sensitive traps are triggered early, leaving traps in a more sheltered position and those with a less sensitive response open. Only 6 to 12% of the traps in the field of view were closed by intense rain. Even rain so heavy that the traps were submerged in water left most of the traps open. Gentle rain can close traps, but this is not a common event. The necessity of two or more stimuli to close a trap accounts for traps general lack of responsiveness to raindrops in light rainfall. Traps observed to be closed by raindrops began reopening in an average of 4.5 hours and full reopening averaged 15.8 hours. Since partially open traps are capable of capturing prey, the average trap closed by rain is effective at trapping in about 12 hours. Rainfall is only a minor factor interfering with traps' ability to catch prey.

Introduction

Dionaea muscipula plants growing just inland from Cape Fear in the coastal savannas of the Carolinas are often subjected to torrential rain as well as more moderate storms. Can rain trigger trap closure? If so what intensity of rain is required to close traps?

In his book Insectivorous Plants (1875), Charles Darwin says of *Dionaea* traps that: "Drops of water, or a thin broken stream, falling from a height on the filaments [trigger hairs], did not cause the blades to close; though these filaments were afterwards proved to be highly sensitive. No doubt...the plant is indifferent to the heaviest shower of rain." By contrast, Williams and Pickard (1980), describing earlier measurements Williams made with Frank Lichtner, says 7.4% of 202 traps closed during a day of heavy rain during which no traps captured prey and that on a day with no rain 1.0% of 201 traps closed without capturing prey and 3.0% of traps captured prey. Williams and Lichtner conclude that there are fewer captures in rain, but that at least some traps were closed by raindrops during a day of heavy rain. Both Darwin's experiment, done under artificial conditions with cultivated plants, and Williams' single set of measurements, done with wild plants under natural conditions, in addition to contradicting each other, fail to convincingly answer the question: "Can a *Dionaea* trap be triggered by rain?"

Darwin, like many others who did early research on this topic, believed that a single contact with a trigger hair was adequate to trigger the closure of a trap (Brown & Sharp 1910). It was not until 1902 that Macfairlane (1902) demonstrated that under typical conditions two stimuli were required to close a trap. As early as 1876 Darwin's friend John Scott Burdon-Sanderson (Burdon-Sanderson & Page 1876) had shown that each touch of a trigger hair results in an action potential and that more than one action potential was required to close a trap, but for or over 30 years this requirement was

overlooked. In 1910 Brown and Sharp demonstrated that in ordinary conditions that two stimuli less than 20 seconds apart result in closure and that a few traps responded to two touches a minute apart. From these and many more recent repetitions of the same experiment (Williams & Pickard 1980; Böhm *et al*. 2016) it is clear that any stimulus that will bend a trigger hair sufficiently to produce an action potential, if delivered twice within 20 seconds, should trigger closure under ordinary conditions. It is unlikely that raindrops would be an exception.

It is the objective of this study to observe *Dionaea* traps, in the Florida panhandle coastal savannah during rain, and see if closure triggered by raindrops occurs, and to determine the number of traps closed per hour during heavy rain by comparing closures per hour in dry weather just before intense rain to closures per hour during intense rain. We also will measure the time required for traps closed by rain to reopen.

Methods

Plants in two stands of *Dionaea muscipula* established near Sumatra, Florida on private land within the Apalachicola National Forest on the coastal savannah were used in this study. One was the same as that used by Williams and Scholl (2021a). It is a wet site near a small stand of *Clitonia monophylla* trees that have covered the ground with leaf litter. *Sphagnum* is growing among the *Dionaea* plants. The second was the neighboring Florida population that originated from seed, descended from plants from the Carolinas broadcast 15 to 17 years ago, as described by Williams and Scholl (2021a). These are growing among scattered tall pines in a grassy area typical of a coastal savannah.

Photography and videography were done using the methods described by Williams and Scholl (2021b).

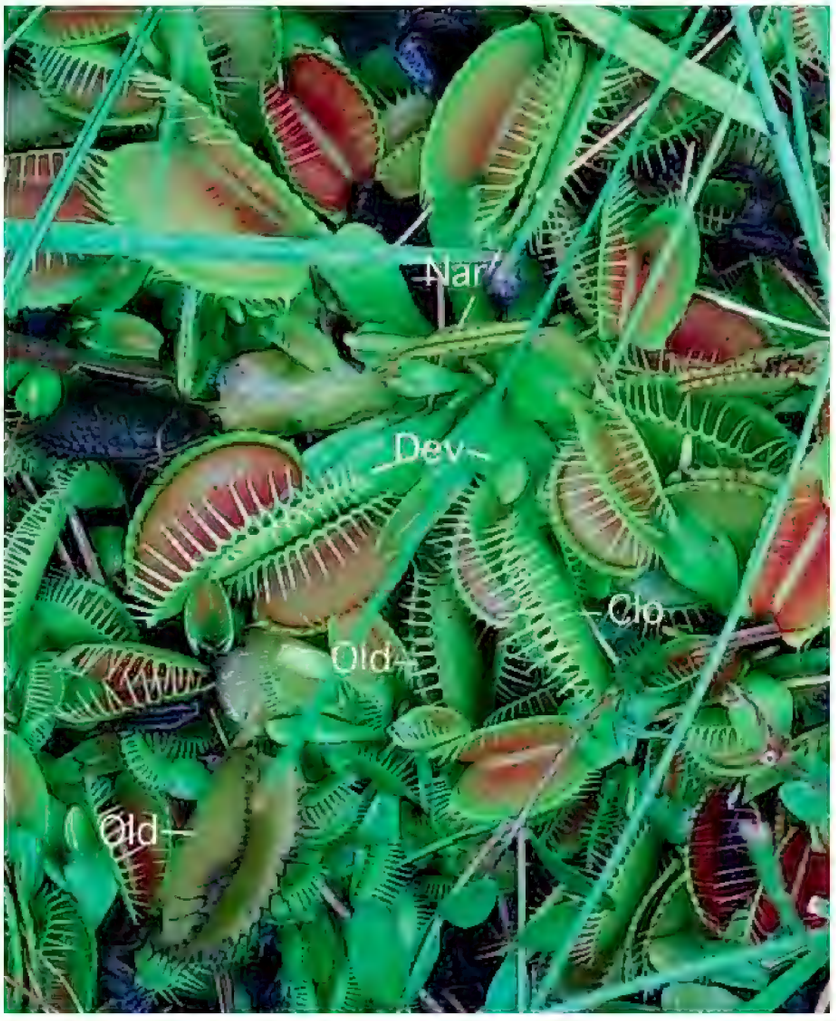

Figure 1: Traps that are not capable of closing are not active traps. These include Narrowed traps (Nar) digesting prey previously captured, Developing traps (Dev) not mature enough to be sensitive, Old traps (Old) no longer capable of responding, and Closed traps (Clo) temporarily closed with no capture.

Method of measuring frequency of trap closure

Definitions of terms used for measurements in this paper:

The terms "closure" and "narrowing" were used by Ashida (1934) for *Aldrovanda* traps. Their use was extended to *Dionaea* by Lloyd (1942).

Trap closure occurs in a fraction of a second and is the flipping of the trap from the open position to the position where the bristles along the edge of the leaf cross each other and only small gaps exist along the rim of the trap. See "Clo" in Figure 1. Closed traps that have not captured prey reopen from the closed position in hours (Fig. 2).

Trap narrowing occurs within minutes of the capture of prey. Mechanical stimulation from the struggling prey and later chemical stimulation from decomposing prey causes trap narrowing (Williams & Pickard 1980). Narrowed traps' lobes close tightly together, sealing along a smooth area just inside each trap lobe. The bristles along the edge of a narrowed trap are forced outward giving a narrowed trap a distinctive look. See "Nar" in Figure 1.

Active traps, as used in this study, refers to traps that are capable of closing. Since artificial triggering of trap closing would interfere with our observations, which were made continuously over long periods of time, estimates of the number of active traps were used in calculations.

Traps in Figure 1 that are not active traps include **Old traps** (Old) that no longer can close, **Developing traps** (Dev) not mature enough to close, **Narrowed traps** (Nar), and **Closed traps** (Clo).

Frequency of trap closure per day = closures/% of active-traps/day.

Frequency of capture per day = narrowed-traps/% of active-traps/day.

Frequency of closure without capture = (closures/% of active-traps/day) - (narrowed-traps/% of active-traps/day).

Method of measuring reopening time

Reopening time of a trap (Fig. 2) that has not narrowed was measured by subtracting the time when the trap was closed from the time when the trap was fully reopened. We also determined the time between trap closure and the time when the trap first began to move its lobes apart.

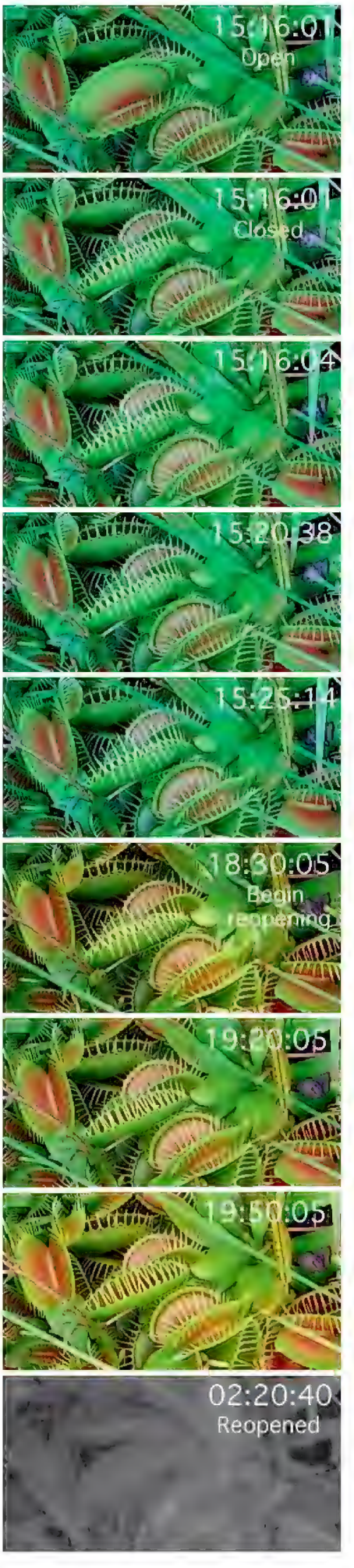

Figure 2: A trap closed by gentle rain. The top frame and second frame show an open trap that was closed a tenth second later. The frames are from a one-minute video in which raindrops were visible and audible with no other detectable stimulation. This was the only trap in the visual field that closed. The trap slowly tightened during the next 3.4 hours after which it began reopening. It was fully reopened after 11 hours. Partially opened traps, slightly more open than that in the second to last frame, have been observed to capture prey.

Table 1. Frequency of trap closure during 25-minute periods before, during, and after a period of intense rain.

	Before rain No rain	Intense Rain	After rain No rain
Active traps	155	155	145
Closed	0	10	0
Time (min)	25	25	25
Closure/% of active-traps/hr	0	15.5	0

Results and discussion

Closure triggered by rain: During gentle rain, closures caused by raindrops are infrequent enough that they are undetectable by statistical means. However, occasional instances of a trap closing in light rain, with no visible stimuli other than raindrops, have been recorded on video (Fig. 2). The response during heavy rain is a different matter. Table 1 shows the response of traps to a cloudburst that produced 25 minutes of intense rain. Of the 155 active traps in the camera's field, ten traps were triggered to close by the raindrops. Among active traps capable of closing, there were no closures that occurred during the 25-minute period before the cloudburst or the 25-minute period after the cloudburst. By contrast, during the cloudburst the traps closed at a frequency of 15.5 closures/% of active-traps/hour. Measurements of trap closures made over 10 days without rain show an average frequency of closures without capture on a dry day as 2.1 closures-without-capture/% of active-traps/day — the frequency of closure triggered by heavy rain was 177 times greater. Another very intense burst of rain closed 12% of the 65 active traps in less than 5 minutes (Fig. 3) and covered 1/3 of the *Dionaea* plants with water within 15 minutes. These traps closed at a frequency over a thousand times greater than closure frequency that would be expected on dry days. The traps were about half open 12 hours later (Fig. 3). Tropical storms are common in both the Florida panhandle and the coastal area of the Carolinas so rain of this magnitude is not unusual.

Raindrops in a heavy rain are capable of triggering closure at a frequency hundreds of times more frequently than they would normally in dry weather. Clearly *Dionaea* traps can be closed by a heavy shower of rain. Of course, this rapid frequency of closures cannot continue long for several reasons:

1. The active traps would be used up, lowering the frequency by reducing the number of active traps
2. The most sensitive traps would close first leaving the less sensitive traps
3. Traps oriented with their trigger hairs most exposed would be closed first leaving those less vulnerable to raindrops

Of the ten traps closed by raindrops, eight were positioned with the trap facing directly upwards, offering maximum exposure of the trigger hairs to raindrops.

Reopening of traps closed by rain: Traps closed by rain are never tightly closed (Fig. 2) because once the traps are closed the trigger hairs are protected from further stimulation by raindrops. Trigger hairs of traps closed by raindrops are likely to have only received two stimuli.

While very slow relative to the time required for closure, healthy traps are usually open before the next day. The average trap closed by rain began to open in 4.5 hours and was completely open in 15.8 hours (Table 2). The fastest opening of the ten traps timed, began opening in 2.5 hours and

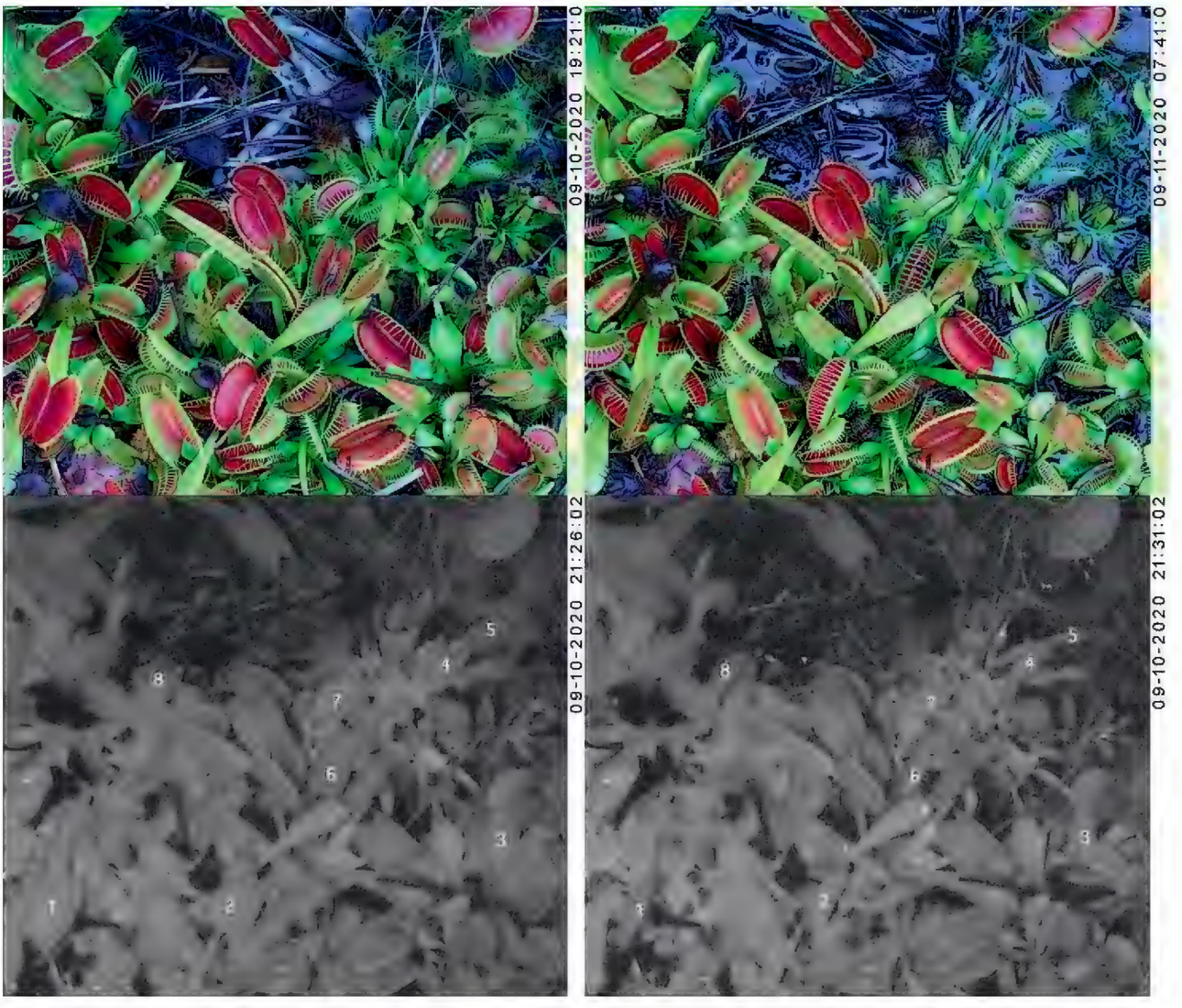

Figure 3: Trap closure caused by heavy rain. Upper left: The area before closure viewed in the light. There are 65 active traps. Upper right: The area the next morning, 10 hours after the trap closures. The closed traps are reopening. Lower left: Traps in the dark just before a burst of heavy rain closed them. Lower right: the traps just after closure. The numbered traps are the eight that closed during the 5 minutes between the two photographs.

was fully reopened in 8.5 hours. Traps do not need to be fully open to be functional. We have video showing traps that are partially open capturing prey.

Traps low responsiveness to rain: Raindrops from a gentle rain do not typically cause traps to close, although there are a small number that do. However, sudden heavy rain showers cause some of the more sensitive traps with exposed trigger hairs to close. After an initial burst of closing during a heavy rain shower, most of the traps remain open even when the rain is so heavy that they become submerged in water. In general, *Dionaea* traps are not highly sensitive to rain because only traps oriented such that drops would directly strike their trigger hairs would be affected. Of these, most would not have hairs struck by raindrops twice within the 20-60 seconds required for a response. In a very heavy rain shower only properly aligned traps are likely to receive two rapidly delivered stimuli and close.

While Darwin is incorrect when he says that *Dionaea* traps are "indifferent to the heaviest shower of rain", it is true that traps are not highly responsive to rain. Lighter rain showers result in very few trap closures and heavy showers close only the most exposed and sensitive traps. After closure,

Table 2. Time required for traps closed by raindrops to reopen.		
Trap number	Time for reopening to begin (hr)	Time of full reopening (hr)
1	4.5	13.5
2	2.5	16.3
3	5.2	7.8
4	2.0	8.5
5	4.0	8.9
6	6.1	15.1
7	3.5	23.5
8	5.4	14.0
9	7.0	27.5
10	5.2	23.3
Average +/- SEM	4.5 +/- 0.17	15.8 +/- 0.76

these traps reopen within about 16 hours. Even partially open traps are capable of capturing prey. It is unlikely that the closure of traps by rain greatly effects prey capture by *Dionaea muscipula*.

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Using a trail camera for recording plant-insect interactions with Venus flytrap as an example

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Abstract: Trail cameras can be used for the study of the interaction between plants and insects if they have a close-up lens and the capability of doing time-lapse photographs or videos. Typical trail cameras are mounted vertically, often on unstable camera stands. We have used the Bushnell NatureView HD Cam Model# 119740 and RC Williams Co. TopView Quick-Mount camera-stand to study the behavior of insects interacting with Venus flytraps (*Dionaea muscipula*). The combination allows photographs and videos to be made of insects and plants from above, with the camera held in a position that allows the plants to be observed from the exact same position for months at a time. Every five minutes a photograph and a one-minute video are recorded. We have developed methods of searching through this data for important events that involve producing "slide shows" of the photographs overlain by a grid, that can be quickly scanned for events of interest. Video of these events near the time of the sequentially numbered photograph can then be viewed. The slides and videos can also be sampled at intervals for more gradual changes.

Introduction

Trail Cameras, also called Camera traps, are commonly used for wildlife photography. Mammologists and ornithologists who study animal behavior have adopted versions of these cameras with close up lenses to observe small birds and mammals (Randler & Kalb 2018; Rovero *et al.* 2013). In these studies, a Passive Infra-Red (PIR) motion sensor is used to trigger the camera when objects warmer than the background move within the range of the sensor. Plants, as well as insects and other arthropods, are not warmer than their background so PIR sensors will not work. However, a camera capable of taking time-lapse photographs can sample activity by arthropods interacting with plants and also follow changes in the plants themselves with time. Camera traps are weatherproof and are capable of recording images during both dark and light periods. A range of close-up lenses allows them to record plants and animals of various sizes as they interact. The major problem is the large volume of data produced where little of interest is occurring. This creates problems with locating photographs and videos with relevant information within a vast sea of data.

We have been using a Bushnell NatureView HD Cam Model #119740 with a 460 mm close up lens to photograph insect and spider interactions with Venus flytrap leaves. The NatureView camera has the capability of making time-lapse photographs and videos. We are using it to take photographs and videos at 5-minute intervals and have developed ways to scan the data for activity so that all data need not be viewed in order to find information of interest.

Another problem we have had is that camera traps and their various camera mounts are designed to be upright in less than stable positions, while for many studies of plants and arthropods, having the camera face downward is the most effective position, and stability is important in any serious photography. We have cooperated with R.C. Williams Co. in the development of the TopView Quick-Mount, a very stable camera mount that points the camera downward.

The object of this paper is to describe the NatureView camera, and the TopView Quick-Mount as used for studying insect-plant interactions. We will cover their features and their limitations and show examples of their performance.

Capabilities

The Bushnell NatureView HD Cam Model #119740 and RC Williams Co. TopView Quick-Mount (Fig. 1) can be used to record the development of plants over extended periods of time (Fig. 2) and record plant insect interactions (Fig. 3 & 4, Williams & Scholl 2021). In daylight the HD videos, that record 30 frames per second, can be viewed frame by frame to measure rapid movements (Fig. 4). The videos and photographs also allow the measurement of the frequency of events, such as *Dionaea* trap closures, and the times of day during which they occur. The camera allows plants and the animals interacting with them to be observed at all hours of the day, over extended periods of time, in all types of weather, without human presence.

Figure 1: (A) The camera and camera stand at site-02 in a Florida coastal savanna. (B) The TopView Quick-Mount camera stand showing the neutral density filter for the IR flash. (C) The NatureView camera with its 460 mm close up lens. (D) Closer shot of the camera and stand showing the foam and foil covering that prevents overheating in direct sunlight.

Equipment

The camera: The Bushnell NatureView HD Cam Model #119740 camera (Fig. 1) can record photographs (JPG files) and also video (AVI files) of 5 seconds to 60 seconds in length. It has a camera mode where only photographs are recorded, a video mode where only video is recorded and a hybrid mode where 1 to 3 photographs are followed after about a second by a video.

The camera is designed to be triggered by a Passive Infra-Red (PIR) motion sensor which is not useful for recording insect plant interactions, but it also has a feature called Field Scan that, in combination with a feature called Interval, can be set to create time-lapse photographs at intervals of 1, 5, 15, 30, and 60 min and videos at intervals of 5, 15, 30, and 60 min. A hybrid mode scan also can produce a photograph followed by a video at intervals of 5, 15, 30, and 60 min.

We use a time lapse interval of 5 minutes and a hybrid mode to record a series of 14 M Pixel photographs, each of which is followed by a 1920 × 1080 resolution HD video clip 1.0 min in length. A 128 GB SD card will store over 3.5 days of data.

With a 460 mm close up lens the NatureView camera covers a 25 cm × 35 cm field of view at a distance of 46 cm in photographs and 15 cm × 24.5 cm in videos. Objects between 39 cm and 57 cm from the lens are in focus.

The camera has an IR flash system that allows nighttime photographs and videos. Eight of the 40 IR LEDs are used when the flash is set for "Low". This is still far too intense for close up photography. A holder has been added to the TopView Quick-Mount that allows stainless steel sieve screening to be used as a neutral density filter that lowers the IR intensity to usable levels (Fig. 1). Nighttime photographs and videos are, at their worst something like an ultrasound image, and at their best like a grainy black and white photograph (Fig. 5), but they allow a view of behavior that is otherwise impossible to achieve.

Figure 2: This sequence of photographs follows a single *Dionaea* leaf from July 6 when its trap was not fully open until September 25 when it was dead. The camera stand was adjusted slightly between 8/27 and 9/17 to improve the focus, otherwise all shots were made without changing the camera's position. On 7/27 the trap captured a grasshopper large enough that the lobes of the trap could not come completely together. By the next day (7/28) ants were visiting the trap and feeding on the partly digested grasshopper. The ants attracted an Oak Toad (*Anaxyrus quercicus*) that fed on them for a while. The trap resealed (8/7) and then partly opened (8/27) but was never functional again except as a photosynthetic organ. The trap began to die about 9/21 and was dead by 9/25.

The camera mount: Figure 1 shows the Bushnell NatureView camera mounted on an RC Williams Co. TopView Quick-Mount. The camera can be removed to change SD cards and batteries, and to reset the clock. After maintenance operations, the camera can be placed back into the exact position it was previously in. The three legs are 5/16-inch galvanized threaded rod cut to the length required. With the legs pushed into the ground, the platform is stable enough that we have taken photographs of the exact same area over several months with no noticeable deviation in the field of view covered by the camera. The camera mount is HDPE machined to exactly hold the camera so that no strap or fasteners are needed to hold it in place.

Figure 3: The top photograph (JPG) has been overlain with a grid and had a white border added. The yellow rectangle in the center of the top photo delineates the area that will be visible in the video. An individual frame from the video (AVI), recorded just after the photograph, is pictured below the top photograph. It is from 18 seconds after the first frame. Note that there is a weevil on the stick that does not appear in the photograph above. This video was located by scanning through a “slide show” of photographs similar to the top one and locating a trap that closed between the photo pictured and the following photo taken at 19:05:01 part of which is pictured in the 5th square at the bottom of the illustration. The trap, in grid section B3 of the photograph at the top of the page, snapped shut after the weevil entered it. Sections from the frames of the video show the weevil entering the trap and being captured. Four minutes after the capture video the weevil forces its way out of the trap as can be seen in the last two frames in the bottom series.

Figure 4: Closure of the trap triggered by the weevil in Figure 3. Individual frames of the video were recorded at 30 frames a second, 33 ms (0.033 seconds) per frame. The beginning of trap closure occurred between the first frame in the second row (00 ms) and the next frame (33 ms). The rapid phase of trap closure was complete by 67 ms. A slower phase of closing occurred between 67 ms and 48.6 seconds when the trap was fully closed. Time zero is the last frame of the video where the trap was fully open. Frames before time zero are listed as negative numbers. The temperature at closure was measured by the camera as 35°C. This figure was composed by Siegfried Hartmeyer using EDIUS X PRO video editing software.

Shadows of the camera and mount are evident in photographs and videos taken on clear sunny days. On hot days when the camera is in direct sunlight the horizontally mounted camera is subject to overheating. The overheating problem was solved by placing an aluminum foil covered Starfoam board over the camera to protect it (Fig. 1).

Data storage: Bushnell recommends using SDHC cards of up to 32 GB capacity, but we have used 64 GB and 128 GB cards without problems. Larger 256 GB cards will not work. The camera formats SD cards with FAT 16 format, which is readable by both MacOS and Windows operating systems. A 128 GB card holds about 3.5 days of our data and a 64 GB card holds about 1.75 days of data. Shooting lower resolution video and photographs will allow far more photographs and video clips to be stored on a card.

Power: Recording photographs and video in hybrid mode at the resolution we use will use up a set of 12 alkaline batteries in recording the 42 hours of data that will fill a single 64 GB card. The camera can be powered externally using an AC Power Adapter, allowing 128 GB cards to be used. An AC adapter can be used inside and, in a garden, where power is available. We have used an AC power adapter with a 200-foot extension cord to power a camera at one of our field sites. We have also successfully used three 6-volt, rechargeable 4-AH lead acid batteries in paral-

lel. AC power adapters and rechargeable batteries are both much less expensive and more environmentally friendly than using AAA cells. However, AAA cells should be kept in the camera to hold the settings when it is not plugged into a power source. The IR flash uses a lot of power. Battery life is greatly extended if the camera is run in daytime mode.

Figure 5: An image of a large spider walking over *Dionaea* leaves at midnight. It measures approximately 6.5 cm from the tip of its front leg to the tip of its back leg. The image is typical of those recorded in the dark with the IR flash. Note that the traps are visible. Their closures during the dark period can be detected.

Organizing and storing data

The data on the SD card is in folders of 999 or fewer files. After data collection our 128 GB SD cards have three folders with alternating JPG and AVI files ordered by file name within a folder. The name is a number like 09110168 where 0911 indicates that the photograph or video was taken on, September 11, and 0168 indicates it is the 168th file in the folder. If a 128 GB SD card is full it will have three folders in it. The first two folders will have 999 files in them and the third will have 42 files. The files can be sorted by type resulting in AVI files rising to the top of the list. The JPGs can be placed in a separate folder resulting in a folder of JPG files and a folder of AVI files. The folders can be named with the date of the first file they contain followed by AVI or JPG. File 251 JPG will have been taken a second before file 252 AVI. This allows the photographs to be matched with the videos.

We use the application, BatchPhoto, to put a grid on every JPG file in the folder (Fig. 3). This serves like the grid on a map and allows the location of traps within the photograph. It also outlines in yellow the area that will appear in the videos.

The JPG files with the grid can be added to an Apple Photos or Windows Photo library and a slide show created. The slide show can be quickly scrolled through while watching one sector of the grid while looking for changes such as trap closures, the appearance of animals, etc. The file number, date, and time when these events occur can then be noted. After scrolling through the slide show making notes on all sectors, the videos where the event occurred can be viewed. Since one minute of every five is recorded on video there is a 20% chance that the event, such as a trap closure was captured on video. The events can also be tallied and their frequency of occurrence can be determined, as can the distribution of times at which the events occurred.

In the light video is recorded at 30 frames per second. The sequence of video frames taken every 33 ms can be used to record the time required for rapid events to occur (Fig. 4).

Once an event, such as the capture of an insect, is recorded the behavior of the trap can be followed and the time of reopening determined. In the extreme, the entire life of a leaf can be followed over a period of many weeks (Fig. 2).

Conclusion

While camera traps have been very useful for documenting warm-blooded animals, plants and insects cannot be photographed using PIR triggered cameras. Properly positioned camera traps with time-lapse capability allow photos in all weather, day and night, over extended periods of time. Methods of searching the photographs and videos for activity then allow studies of plant insect interactions. We have successfully observed the interaction between *Dionaea* traps and visiting insects and spiders and between *Dionaea* flowers and their visitors (Williams & Scholl 2021).

Even without being able to use its PIR sensors, the camera trap opens up a window allowing a view of the relation of insects and plants. It takes more patience than using a deer camera looking at big game does, but it offers the opportunity to see what no one has seen before.

Acknowledgements: We would like to thank Rick Williams of RC Williams Co. for designing the camera holder that played a crucial roll in this research. We thank Dr. Susan Verhoek of Lebanon Valley College for constructive comments on the research. Figure 4 is by Siegfried Hartmeyer who separated the video stills with EDIUS X PRO video editing software**.** We also thank Dr. Bruce Means, of Florida State University for identifying the Oak Toad *Anaxyrus quercicus* pictured in Figure 2.

Disclosure: The authors have no financial interest in either Bushnell Corp. or RC Williams Co.

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On *Dipsacus* and *Drosera*: Francis Darwin's favorite carnivores

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Keywords: *Dipsacus*, *Drosera*, Francis Darwin, carnivory, insectivorous plants, common teasel.

Abstract: In autumn of 1875, Francis Darwin was busy researching aggregation in the tentacles of *Drosera rotundifolia*. This phenomenon occurs when colored particles within either "protoplasm" or the fluid in the cell vacuole (the cell sap) cluster together. Charles Darwin had theorized in the book Insectivorous Plants that these aggregated cellular masses consisted of living protoplasm. Inspired by his investigation of *Drosera*, Francis set out to examine the cup-like receptacles formed by the leaves of *Dipsacus fullonum* (synonym *D. sylvestris*), commonly known as fuller's teasel. Francis went on to suggest that the common teasel might be a carnivorous plant, acquiring nutrients from decaying insects drowned in its water-holding basins. Since then, other biologists have evaluated these claims with little experimental success. This paper provides a historical overview of Darwin's experiments with *Dipsacus* based on extant correspondence, discussing his results in the context of later studies that examine this unusual adaptation.

Introduction

Charles Darwin's enthusiasm for carnivorous plants is well documented. As early as 1860, soon after encountering the sundew *Drosera rotundifolia* on an English heath, the Origin of Species author wrote, "I care more about *Drosera* than the origin of all the species in the world" (Secord *et al.* 2020, Letter no. 2996). Darwin's rigorous experimentation with these enigmatic killer vegetables culminated in 1875 with the publication of Insectivorous Plants. This treatise laid the framework for the study of plant carnivory as it exists today and cemented the notion of carnivorous plants in the scientific and public imagination.

Darwin's son, Francis, carried on his father's legacy in a variety of ways, including through his own scientific ventures into plant carnivory. Francis' passion for carnivorous plants first stemmed from aiding in his father's work on Insectivorous Plants, in which he is credited with illustrating the tiny underwater traps of *Aldrovanda* and *Utricularia. Drosera*, however, was the resounding favorite of both father and son. Nearly two-thirds of Insectivorous Plants is dedicated to the sundew. Having firsthand experience with his father's experiments, Francis sought to elaborate on the book's findings shortly after the first edition was published.

In autumn of 1875, Francis Darwin was busy researching aggregation in the tentacles of *Drosera rotundifolia* (Darwin 1876). This phenomenon occurs when colored particles within either "protoplasm" or the fluid in the cell vacuole (the cell sap) cluster together. Darwin senior had theorized in Insectivorous Plants that these aggregated cellular masses consisted of living protoplasm (Secord *et al.* 2020, Letter no. 10134A). Inspired by his investigation of *Drosera*, Francis set out to examine the cup-like receptacles formed by the leaves of *Dipsacus fullonum* (synonym *D. sylvestris*), commonly known as fuller's teasel (Fig. 1). In The Loves of the Plants (1789) his great-grandfather, Erasmus Darwin, wrote that each dew-filled cup "serves both for the nutriment of the plant in dry seasons, and to prevent insects from creeping up to devour its seed." Francis, however, expected to find that the decaying insects known to accumulate in these cups were being absorbed by the plant. Unfortunately, the glandular hairs of his specimens were too withered for observation and he postponed

work until the following summer. Using "some Teazle seeds" sent to his father from Kew Gardens by Joseph Dalton Hooker, Francis began growing his own specimens and continued collecting wild plants in the spring of 1876 (Secord *et al*. 2020, Letter no. 10282). The resulting observations would substantially further his foray into deciphering plant carnivory.

"Hooray theory. Blow facts."

On 28 May 1876, Francis wrote to his father that he had observed the protrusion of protoplasmic masses by the cells of *Dipsacus* glands, emphatically exclaiming "Hooray theory. Blow facts" (Secord *et al*. 2020, Letter no. 10515J). Francis drew comparisons to "the absorption of fat in the intestines" of animals by similar "protoplasmic feelers" and speculated that they may be the precursor to slimy secretions capable of catching live insects. Still finishing his article on aggregation in *D. rotundifolia* tentacles, Francis had to delay further examinations (Secord *et al*. 2020, Letter no. 10515I). His father encouraged pursuing this line of investigation and suggested further observations, imploring Francis "I would work at this subject if I were you, to the point of death" (Secord *et al*. 2020, Letter no. 10517).

Figure 1: The connate leaves of *Dipsacus fullonum* form a water-holding basin. Sowerby (1865) plate 675.

At this time, Darwin senior was responding to critiques that Insectivorous Plants failed to conclusively prove these plants benefited from the absorption of insect matter. He was optimistic that by examining the effects of insect prey on growth and reproductive vigor (measured as biomass and quantity of seeds) such proof could be obtained and nudged his son towards attempting these "Seed-bearing" experiments with *Dipsacus* (Secord *et al*. 2020, Letter no. 10517). While Darwin was "curious if the movements of the protoplasm depend on the excitement of ammonia or nitrogeneous matter", he also cautioned his son to "Take care and do not overwork and kill the goose that lays the golden eggs" (Secord *et al*. 2020, Letter no. 10525).

With his father's encouragement, Francis recorded "splendid protoplasmic movements" by exposing the glands to infusions of raw meat and carbonate of ammonia (Secord *et al*. 2020, Letter no. 10515H). After witnessing this "grand discovery" himself, Darwin excitedly described the protoplasmic masses and movements to George John Romanes, FRS (Secord *et al*. 2020, Letter no. 10526, 10520). In late June, Darwin confided to his friend J.D. Hooker, "I have hardly a doubt that here we have a plant catching & feeding on solid particles of decaying insects" (Secord *et al*. 2020, Letter no. 10542).

Francis consulted with William Thiselton-Dyer of Kew Gardens by early July, and Darwin wrote to his second son, George Howard: "Frank is getting on very well with Dipsacus, & has now made experiments which convince me that the matter which comes out of the glands is real live proto-

plasm, about which I was beginning to feel horrid doubts." "Oh Lord what a set of sons I have, all doing wonders" (Secord *et al.* 2020, Letter no. 10556, 10561). Aside from a passing mention of Frank's endeavors to Asa Gray, there is no extant correspondence on the matter for the rest of the summer (Secord *et al.* 2020, Letter no. 10575). Although it can be surmised that Francis privately carried on with his observations.

On 7 September 1876, Francis welcomed his son Bernard into the world. He was the Darwin's first grandchild. However, tragedy soon struck the Darwin household. Francis' wife, Amy, died just four days after the birth of their son. Unable to live in their home in Down village, which reminded him so much of his life with Amy, a devastated Francis left for Wales with his in-laws, the Ruck's, a few days after her death. Bernard remained with his grandparents in Down. Worried that his son's despair would weaken his will to pursue scientific endeavors, Darwin gently yet consistently encouraged further work on a *Dipsacus* paper and frequently sent reading material to Wales (Secord *et al.* 2020, Letter no. 10611). Having suffered the deaths of two children, Darwin deeply believed in the value of finding solace through one's work. Francis entered a reclusive and hardworking state of mourning, continuing to work with *Dipsacus* as a distraction from his grief, and returned to Down House in mid-October (Secord *et al.* 2020, Letter no. 10635F, 10644). He spent the remainder of the year in his childhood home, authoring the *Dipsacus* paper and proofreading Darwin's second edition of Orchids (1877).

Initial publication and Royal Society reception

By January of the following year, the paper was nearly ready for publication, and Darwin senior submitted his son's discovery to the Royal Society of London. Only fellows of the Royal Society could submit research papers, and Francis was not yet a fellow. Personally, Darwin had high hopes that "its being printed...would stimulate his zeal & make him think better of his work" (Secord *et al.* 2020, Letter no. 10814). Francis read his paper "On the protrusion of protoplasmic filaments from the glandular hairs of the common teasel (*Dipsacus sylvestris*)" at the Royal Society on 1 March 1877. His address was received with great "pride & satisfaction" from longtime family friend J.D. Hooker, who worked extensively with the carnivorous tropical pitcher plant *Nepenthes* at Kew Gardens (Secord *et al.* 2020, Letter no. 10873). To this Darwin responded with equal enthusiasm, admitting that "Dipsacus will have to be examined by other good workers; but I do not think that anyone [could] see their spontaneous action & doubt that they were formed of living matter" (Secord *et al.* 2020, Letter no. 10874).

An abstract of Francis' paper was published in the Royal Society's Proceedings, but to his father's malcontent the society neglected to print it in full: "The [Royal Society] Council have refused to print Frank's paper on the Teazle glands—on what grounds I know not. I have not been so much mortified for many a year; but he does not care much, all such things being mere trifles to him. My opinion about the value of his work remains quite unchanged & I care not who the referees may have been" (Secord *et al.* 2020, Letter no. 10971). The full paper, complete with several of Francis' drawings and a plate of sixteen figures, was published July 1877 in the Quarterly Journal of Microscopical Science (Fig. 2).

Francis presented several key conclusions in his abstract: "the filaments contain true living protoplasm", "Dilute infusions of meat cause ... astonishing quantities of transparent matter [to be] produced", and "The protrusion of protoplasmic filaments from the glands of the teasel appears to bear an obscure relationship to the phenomena of 'aggregation' in *Drosera* and several other plants." He believed that the leaves were "adapted for the capture of insects whose decaying remains are

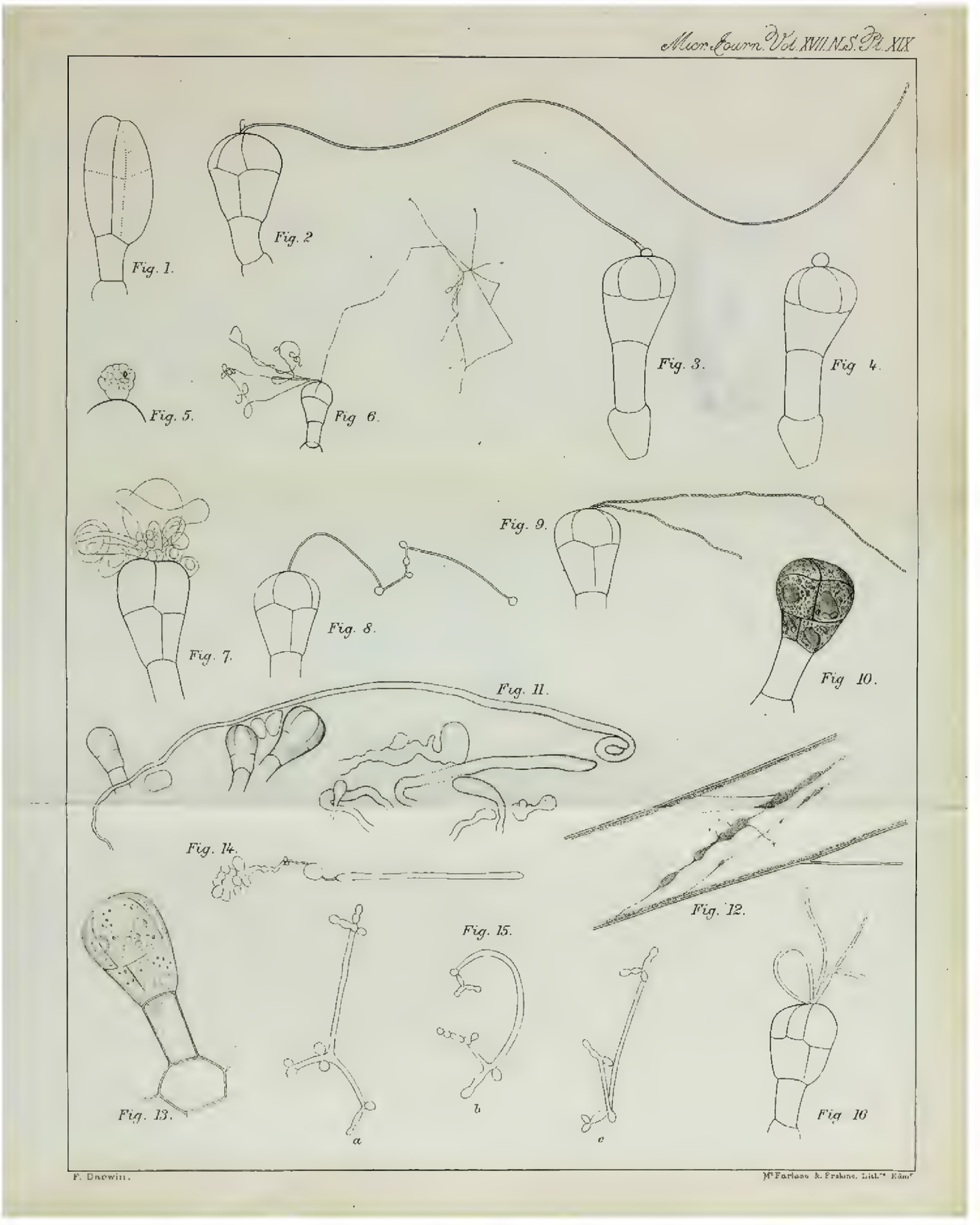

Figure 2: Plate from Francis Darwin's 1877 paper on the common teasel (*Dipsacus sylvestris*). Quarterly Journal of Microscopical Science s2-17(67): plate 19.

absorbed by the plant" and "form a pair of treacherous slides leading down to a pool of water." Francis stipulated that the protoplasmic filaments evolved first to absorb ammonia in accumulated rainwater, then adapted to consume drowned nitrogenous insect matter (Darwin 1877a). In his full paper, Francis proposed an experiment in which "teasel raised from seed under similar conditions will be divided into two lots, one half being starved and the other fed with insects or pieces of meat",

not unlike his experiments on the growth and reproduction of *Drosera* (Darwin 1877b). There is no record of Francis following through with these plans.

An "extraordinary discovery"?

After its initial publication, Francis forwarded copies of the *Dipsacus* paper to several prominent scientists within his father's network of correspondence; most notably F.J. Cohn, Alphonse de Candolle, and Asa Gray. Cohn was particularly receptive to the "extraordinary discovery" and at Darwin's request successfully replicated Francis' observations by the beginning of August (Secord *et al.* 2020, Letter no. 11093). Still displeased by the Royal Society's decision not to publish the full paper, Darwin responded "I can declare that I have hardly ever received [a letter] in my life which has given me more pleasure. I have reason to know that some of our leading men of science disbelieve in my son's statements, & this has mortified me not a little" (Secord *et al.* 2020, Letter no. 11095). At Darwin's request, Cohn agreed to allow an excerpt of his letter to be published in Nature, corroborating some of the "vital phenomena of protoplasmic pseudopodia" emerging from the teasel glands. Cohn's observations appeared in the journal by the end of the month (Darwin 1877). Although, as Darwin pointed out in a letter to G.J. Romanes, Cohn was hesitant to "pronounce whether the filaments are some colloid substance or living protoplasm" (Secord *et al.* 2020, Letter no. 11096).

On New Year's Eve Cohn revisited his initial reservations and wrote to Darwin that "after maturer reflection, I am convinced that there is no living phenomenon" taking place in the teasel filaments (Secord *et al.* 2020, Letter no. 11298). Cohn instead favored an entirely mechanical explanation, in which the exosmosis of water was responsible for the movement "of those curious filaments, protruding, undulating and retiring in the most extraordinary way" (Secord *et al.* 2020, Letter no. 11298). As early as August 1875, Cohn had argued that aggregation in *Drosera* resulted from the "partial precipitation of certain substances dissolved in the acid cell-fluid, in consequence of the exosmosis of the acid" (Secord *et al.* 2020, Letter no. 10137). While Cohn was mostly aligned with Darwin on the digestive properties of the protoplasmic *Drosera* exudate, he disagreed on the nature and function of aggregation. Francis' 1876 paper on aggregation sought explicitly to support his father's theory over Cohn's. That is, the aggregated masses consisted of protoplasm, rather than condensations of cell-sap (Darwin 1876). Cohn's comments on *Dipsacus*, however, went a step further. He became convinced that the exudate had no active (i.e., digestive) properties and was therefore not protoplasmic in nature.

Darwin was quick to defend his son, responding that Francis "has lately made some observations which incline me very strongly to believe that the filaments consist of living matter of the nature of protoplasm" (Secord *et al.* 2020, Letter no. 11310). He is referring to Francis' experiments on *Amanita* (*Agaricus*) *muscaria* (the fly agaric mushroom), from which Francis concluded that the filaments of both *Agaricus* and *Dipsacus* contracted as a result of living protoplasmic matter, rather than the endosmosis and exosmosis of water. When Francis witnessed the effect of salt and acid solutions on the filaments of both organisms, he conceded that "The two cases must sink or swim together" (Darwin 1878b). In this follow-up paper, he made it clear that his main research question was "Are the filaments protoplasmic or not?" This query took precedence over theories about the function of the filaments, and Francis distanced himself from his earlier speculation as to their carnivorous tendencies.

Indeed, after publishing his second *Dipsacus* paper, Francis appeared altogether done with the topic. Darwin attempted to nudge his son back towards "The Teazles" in the summer of 1879, exclaiming that they "look magnificent in the orchard, & I hope next year you will grapple with the

subject again, for I am sure that it is worth it" (Secord *et al.* 2020, Letter no. DAR 211:25). As late as 1881, less than a year before his death, Darwin himself was experimenting with teasel leaves (Cambridge Digital Library). Yet it seems the coaxing of his father was not enough to rekindle Francis' scientific pursuit of the curious filaments. This is not to say his carnivorous curiosity was satiated completely. In 1888 he would publish a revised 2nd edition of Insectivorous Plants. Although there was no further mention of *Dipsacus*, Francis accepted that he and his father had erred on the nature of aggregation in *Drosera*: "there can be no doubt that the aggregated masses are ... precipitations of the cell-sap, and that their supposed amœboid movements are the result of the streaming protoplasm, which moulds the passive masses into a variety of forms" (Darwin 1888). Today, the "protrusions of protoplasm" beyond cell boundaries described by Darwin would typically be regarded as cytoplasmic exudates.

Dipsacus beyond Darwin

Extant correspondence tells us that Francis Darwin's observations of *Dipsacus* were the natural continuation of a scientific legacy firmly grounded in his father's work. Although many of Darwin's experiments remain the foundation of modern carnivorous theory, he avoided any extensive discussion of their evolutionary development. Francis' examination of *D. fullonum* provided a "missing link" of sorts, in that he believed this plant had evolved protoplasmic features for other purposes, but that they had begun to benefit the plant in carnivorous ways. This discovery opened the door to the scientific evaluation of sub-carnivorous plants, further blurring the increasingly complex boundaries of the plant kingdom.

Detractors of Charles Darwin's carnivorous theory frequently pointed out that so-called carnivorous plants flourished in European hothouses year-round without any insect prey to feed on. Experiments executed during the writing of Insectivorous Plants attempted to address this quandary but failed as all the plants, fed or not, had died. Francis returned to his father's beloved *Drosera rotundifolia* in June 1877, finding sundews that had been "fed" doubled in seed production and size (Darwin 1878a). Since these early experiments, many carnivorous genera have been proven to demonstrate increased size and biomass when the plants are supplemented with insect prey.

By the early 20th century, biologists inspired by Francis Darwin sought to determine the common teasel's status as a carnivorous plant. In 1904, Rostock published a wide-ranging study on the glands, their curious "filaments" and the absorptive properties of *D. fullonum*, finding no detectable absorption of various nitrogen compounds by the cups. His study involved several feeding experiments in which the test group was supplied insect prey, while the cups of one control group were slit open so that they could not hold water, and water in the cups of another control group was replaced daily so that nutrients/prey could not accumulate (Rostock 1904). At the conclusion of the experiment all observed parameters (size, robustness, fertility) were essentially comparable regardless of treatment. Only the control with perforated cups was less strongly branched (possibly because buds were injured by the cuts) and consequently these plants produced fewer fruits (Rostock 1904). Thus, Rostock determined that the cups did not provide any meaningful nutritional benefit to the plants.

Nearly two decades later, Miller Christy (1923) offered abundant circumstantial observations and speculations but very little experimental evidence for his bold assertion of "The common teasel as a carnivorous plant." Admitting that he had "no conclusive proof", Christy's claims have remained largely anecdotal. Later authors such as Juniper, Robins and Joel (1989) did not consider *Dipsacus* to be carnivorous. Additionally, while Cohn (1878) assumed osmotic expansion of an exudate, Senft (1907) provided a more plausible explanation by attributing the filaments to "myelin

figures." Long, thin, cylindrical structures that form spontaneously at the interface between certain lipids/surfactants with water, their movement is driven by abiotic forces and often creates dense tangled masses like those observed by Darwin. Senft's interpretation appears to have held up over time, although the work of both Senft and Rostock has been mostly ignored in recent literature — with the notable exception of Vogel (1974), who discussed these so-called myelin figures in some detail.

Despite — or perhaps simply unaware of — Rostock's discouraging findings, contemporary attempts to replicate these experiments on the common teasel continue to fuel debate over whether or not *Dipsacus* truly boasts a carnivorous appetite. A 2011 study (Shaw & Shackleton 2011) revealed significant differences in seed production dependent on both amount and nature of introduced animal supplementation, while 2019 experiments suggested that increased seed production was a response to poor soil conditions rather than proof of carnivory (Krupa & Thomas 2019). Krupa and Thomas (2019) further posited that examining the cups as mechanisms of predatory deterrence against insects remains the most plausible untested hypothesis; first proposed by Erasmus Darwin in The Loves of the Plants (1789). Experimental evaluation of this theory is a sound next step in solving the mystery of *Dipsacus*' unusual adaptation. Although Francis Darwin's initial hypothesis seems to have been promptly proven false by Rostock, his original conviction (shared by his father) appears to be seeing a minor resurgence some century and a half later, and these results are almost certainly not the final words on the matter.

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Re-discovering *Utricularia platensis* Speg. in Argentina

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In 2017, my girlfriend and I were part of the AAPC (Argentine Association of Carnivorous Plants). Within the framework of said institution, which sought to popularize knowledge about these plants and advocate for their protection, several on-site investigations were carried out to register specimens in their habitat.

The only native carnivorous plant of which we had knowledge in the province of Buenos Aires was *Utricularia gibba* L. (Lentibulariaceae) at a few locations. However, there was a particularly elusive species, whose most recent description in the literature was from Peter Taylor's *Utricularia* monograph: *U. platensis* Speg. (Taylor 1989). The last records we could find of this species for Argentina were made by Dawson (1965) and also reports from the Biodiversity Information System (Zuloaga 1996).

Dawson described *U. platensis* as a "common aquatic species in calm waters of Buenos Aires." However, in the intervening decades there has been significant human development in this region, both urban and rural. We could only presume that it still occurred somewhere in the vicinities of Buenos Aires, so we decided to explore, in an attempt to re-discover this rare species.

The location

Argentina is geographically divided into six major regions: Northwest (NOA), Northeast (NEA), Cuyana or del Cuyo Region, Patagonia, and North and South Pampean Plains (Ministerio de Ciencia 2016). In these regions, characteristic relief changes can be found that determine smaller areas with their own geographic, climatic and water properties, known as subregions. The findings described below were made in the subregion of the "humid pampa" or "depressed pampa" that covers most of the central-eastern province of Buenos Aires (Fig. 1). It is characterized by its wide plains and grasslands, abundant quantity of streams, channels, lagoons, and the basins of the Salado and Samborombón rivers. Due to its depressed and flat relief and the scarce runoff from its soils, the humid pampas present large floodplains in the rainy season (Velázquez *et al*. 2014; World Wildlife Fund 2021). According to the inventory of wetlands carried out by the Provincial Directorate of Natural Resources in 2019, the water in this subregion comes from rainfall, groundwater, and surface runoff (Mulvany *et al*. 2019).

Figure 1: Chascomús lagoon area (red box) within the central-eastern province of Buenos Aires, Argentina.

Among the wetlands present in the province, one of the most important (due to its size, biodiversity, and popularity as a tourist attraction) is the one comprised (from North to South) of the interconnected lagoons of Vitel, Chascomús,

Adela lagoon, Salada y del Burro, Chis Chis, La Tablilla, Las Encadenadas, and Las Barrancas (Geographical names according to Google Earth (2020). These are known locally as "the chain system" which in turn are an important weekend getaway destination for urbanites, who go there to fish, boat, camp, etc. As a result, there is significant human impact.

However, it is thanks to this ease of accessibility that we decided to begin our search for *Utricularia platensis* in these wetlands.

The discovery

In the month of February 2017, we took advantage of our summer vacations to begin our exploration of this area. First, we headed out towards an area of flooded terrain along the edge of the Chascomús lagoon (Fig. 2). However, due to a strong storm the previous night, the water was too deep and we didn't get very far, bringing our spirits down as we turned back. It wasn't a total loss though, since on the way back we stumbled across a flowering specimen of *Ibicella lutea* (Lindl.) V. Eselt (Martyniaceae) (Fig. 3)! I had been eagerly hoping to see this "protocarnivore" for a long time, and it gave us encouragement to continue exploring.

Figure 2: The author in flooded terrain along the edge of the Chascomús lagoon.

We slowly circled around the Chascomús lagoon, descending to the shore whenever we could to check among the reeds. This normally happened where a bridge crossed a stream or where a channel flowed into the lagoon. Finally, growing among reeds (*Juncus* sp., Juncaceae) and *Hydrocotyle bonariensis* Lam. (Araliaceae) along one channel, we found flowerless floating stems of an aquatic *Utricularia*, up to ~25 cm in length. Could this be *U. platensis*? Or maybe it was another aquatic species such as *U. breviscapa* Wright ex Griseb. or *U. foliosa* L?

We continued exploring along the shore of the channel to the mouth of the lagoon, but as we got closer, we found progressively fewer and smaller *Utricularia* stems, some as short as 5 cm. Sadly, they were sometimes seen floating alongside glass bottles, cardboard waste, pieces of plastic, and aluminum cans.

In order to identify the plants, we collected a few stems which we later compared with the descriptions and illustrations in Taylor's monograph. He mentions as a key characteristic of

Figure 3: *Ibicella lutea* flower.

Figure 4: *Utricularia platensis* plant, flower, and stolons.

U. platensis that traps are "…inserted in or very near the angle between the [leaf] segments" (Taylor 1989). Looking at our plants, we could indeed see this characteristic … we had rediscovered *U. platensis* (Fig. 4)!

Now we needed to find some in flower. According to the bibliography, *U. platensis* was known to flower towards the end of the year, in our Spring and early Summer (Taylor 1989). So finally, in November 2018, we were able to return to further explore the same lagoons, now with two more members in our group, and with a vehicle to help us cover more ground. Once again, we found small fragments of *U. platensis* stolons in almost all the streams and small tributaries of the Chascomús lagoon. But sadly, no flowers anywhere.

After exploring that area, we headed back to the car and drove a little further along the road that circles the lagoon. We decided to explore down a slope leading to a flooded shoreline, populated by reeds and *Azolla filiculoides* Lam. (Salviniaceae) (Fig. 2). Here, to our immense surprise and joy, we found a large and dense population of *U. platensis*, covering tens of square meters. The stolons were both floating (in water up to 50 cm deep) as well as growing on wet soil closer to the shore. Best of all, there were dozens of inflorescences too! The flowers of *U. platensis* are yellow and the scapes have a characteristic floating structure shaped like a wheel, with 7-9 vertices (morphologically similar to those seen in the closely related species *U. breviscapa*, *U. inflata* Walter, and *U. radiata* Small).

To further understand the ecology and life cycle of *U. platensis*, we returned to this region during autumn, in March 2020. Not a single trace of the plants was found, raising the question of whether

they grow as annuals or perennials. Taylor mentions that small tubers have been observed at the apex of stolon branches, suggesting a possible means of surviving chilly winters beneath the mud.

Acknowledgements: To Belén Arce and Sandra Mantoani for helping to explore for *U. platensis* and also to Jano Nehuén Procopio, student and teaching assistant at the National University of La Plata (UNLP), who also accompanied us and helped identify all the plants seen *in situ*.

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A new technique for the cultivation of *Cephalotus follicularis*

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Jacky Chiem, co-author and owner of Chiem Exotics, a carnivorous plant nursery in Vietnam, received his first small *Cephalotus follicularis* plants in 2017. The climate in Ho Chi Minh City is well suited to tropical lowland plants, but not ideal for a temperate Australian native, resulting in some discussion between the two authors on how best to meet this challenge. It was decided that placing the plants in a chamber, that was successfully being used for highland *Nepenthes* and *Heliamphora*, would give *C. follicularis* the best chance of survival. This in itself is not a new way to cultivate *C. follicularis*, but brings with it some other problems, particularly the plant's susceptibility to rotting and fungal attacks in conditions with poor ventilation. *Cephalotus follicularis* can also have the annoying habit in cultivation of looking vigorous and healthy, and without warning dropping most of its leaves and pitchers.

These issues became the topic of quite a bit of correspondence between the two authors, and what might be done to create a cultural method that would provide the plant with the best chance of long-term survival. This correspondence concluded with agreement that maintaining clean compost, not subject to breaking down or becoming sour would be essential. It is from here that Jacky Chiem applied his considerable horticultural knowledge and skills to devise a cultural method that has seen his plants flourish and multiply. The following is a summary of this technique that produces long-term vigorous growth resulting in large clumps of plants with multiple growing points, that can be divided regularly.

1. Plants are positioned in a highland greenhouse (Fig. 1A) with a temperature range of 15°C at night and 27°C daytime and 80% humidity, this is controlled with an air conditioner and misting. Good light is essential for developing the distinctive dark red colouration of *Cephalotus follicularis*, and this is achieved with a combination of filtered sunlight and LED grow lights (Fig. 1B).
2. Plants are grown in 20 cm deep plastic planter box, with the drain holes blocked (Fig. 2A).
3. A black plastic grate is placed in the bottom of the planter box to create a water well, these generally come with the planter box (Fig. 2B).
4. A 2.5 cm drain hole is made at one end of the planter box between 8 cm and 5.5 cm from the bottom of the box. It is best to insert and seal a 25 mm PVC joiner into the drain hole to promote good water flow (Fig. 2C).

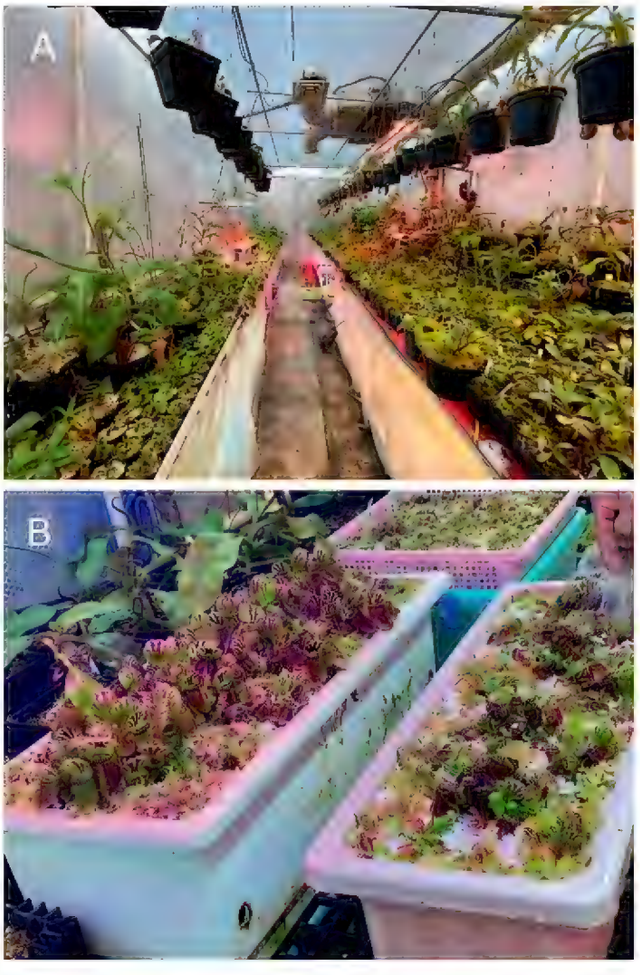

Figure 1: Highland greenhouse and *Cephalotus follicularis* planter boxes.

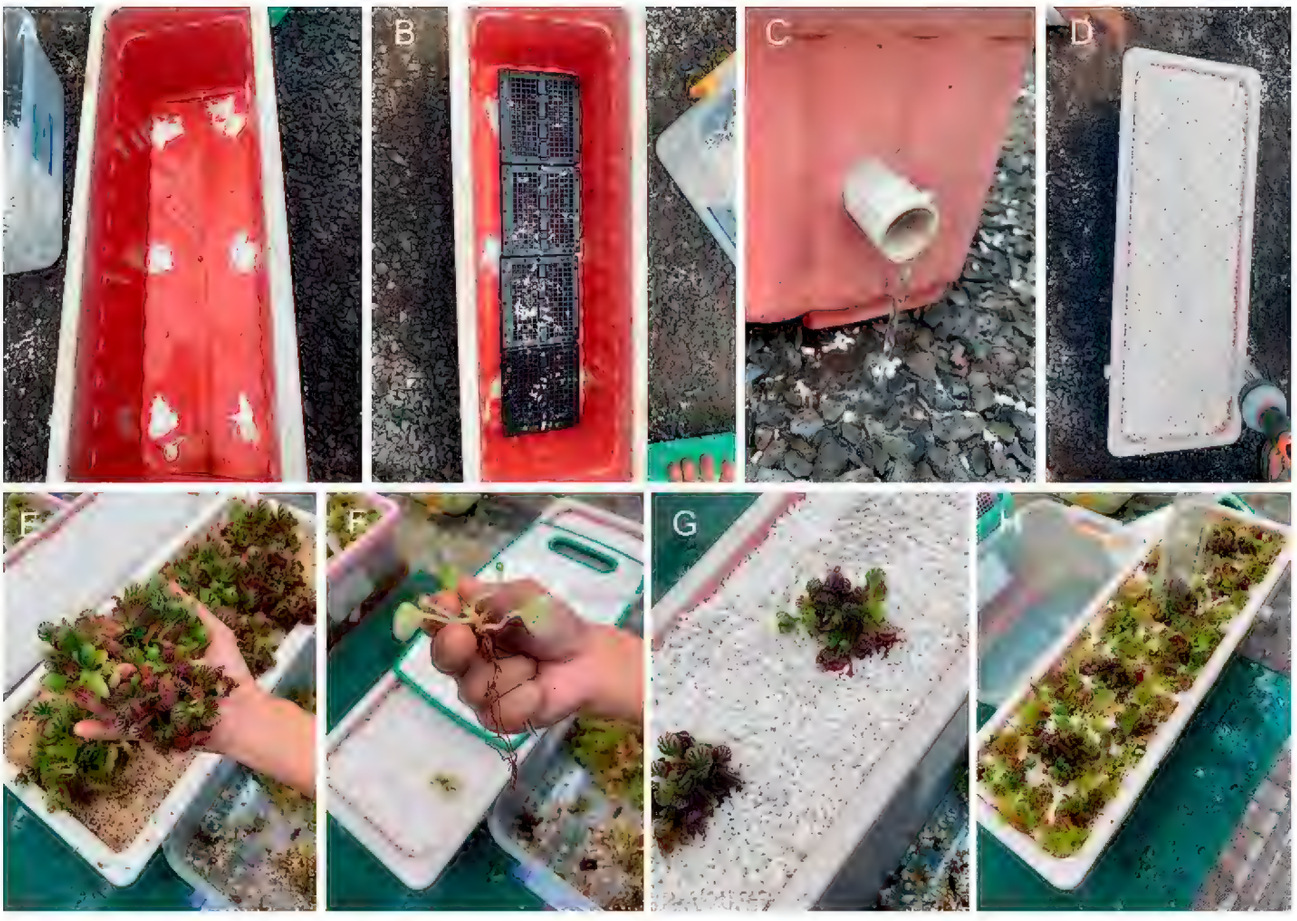

Figure 2: Technique for cultivation of *Cephalotus follicularis*.

5. One of the key success factors for this method, is the use of pure perlite as the compost. Fill the planter box with course grade perlite (Fig. 2D).
6. Water the perlite until excess water is seen overflowing from the drain (Fig. 2C). Once planted out, water every few days to keep water well full and encourage roots to find the water well. Perlite does not hold water well and it is important to maintain this watering regime with discipline.
7. Take a mature clump of *Cephalotus follicularis* and separate the clump into many smaller pieces (Fig. 2E), each with a small bit of rhizome, and wrap the rhizome with a small amount of live sphagnum (Fig. 2F).
8. Plant each division well-spaced into the perlite (Fig. 2G), put a few strands of live sphagnum around the small divisions on the surface of the perlite to help with water retention and surface humidity (Fig. 2H).

The innovations in this cultural method seem to go against the accepted principals for *C. follicularis*. Most growers use a compost that contains peat moss in varying proportions, and keeping the plants in a pot with a permanent water well, would almost certainly lead to problems with rot or fungus, particularly in a closed highland environment. Figure 1B shows an established planter box with about 2 years growth and a recently planted out box with cuttings starting to grow new foliage. Each large clump can provide the starter material for a new planter box, potentially one could exponentially continue this process. The authors are acutely aware that each grower has their own process for cultivating their plants and are not suggesting this as a foolproof method, rather to encourage growers to experiment and try left field solutions.

Keywords: cultvar, *Cephalotus follicularis* 'Squat', *Dionaea* 'EEC Purple People Eater', *Dionaea* 'Magikarp', *Drosera* 'Avaricious Arugula', *Sarracenia* 'Talisman'.

Abstract: Five new carnivorous plant cultivars are named and described: *Cephalotus follicularis* 'Squat', *Dionaea* 'EEC Purple People Eater', *Dionaea* 'Magikarp', *Drosera* 'Avaricious Arugula', *Sarracenia* 'Talisman'.

Cephalotus follicularis 'Squat'

Submitted: 21 February 2021

Cephalotus follicularis 'Squat' (Fig. 1) originates from the late Dennis Hastings collection. The cultivar tends to grow with wide and short pitchers. There is a horizontal protrusion under the peristome giving the pitcher a squat appearance, which is also observable on newly emerging and developing pitchers. Moreover, the base is rounded with a bullet like appearance, further contributing to its squat like characteristic. The peristome is round with short and thin teeth. The shape is stable and very different from the other *Cephalotus*, making it easy to distinguish even without a label.

The name derives from the pitcher's squat looking appearance.

Asexual propagation (vegetative) is required in order to preserve the unique characteristics.

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Figure 1: *Cephalotus follicularis* 'Squat'.

Dionaea 'EEC Purple People Eater'

Submitted: 15 February 2021

Dionaea 'EEC Purple People Eater' (Fig. 2) is the product of a collaboration between Evan Wang and Craig Heath. Hand pollination was performed in the summer of 2018 by Evan, Emmy, and Stephen Wang with isolation of flowers after pollination. The seed was the product of crossing *D.* 'FTS Maroon Monster' with *D.* 'Jaws Smiley'. Numerous seeds from this cross were grown by both Evan Wang and Craig Heath. Of the over 80 seeds, only one (grown in Lorton, Virginia) developed the unique phenotype of *D.* 'EEC Purple People Eater'.

Dionaea 'EEC Purple People Eater' is characterized by dentate-type cilia, similar to *D.* 'UK II' but the cilia are longer. Traps and petioles are green with prominent purple coloration of the petioles and external traps. Trap morphology is reniform with somewhat elongated forms that reflect the *D.* 'Jaws Smiley' parentage. Traps are symmetric and fully functional, able to completely seal and digest prey. Trigger hairs are standard three per trap side. Trap size measures up to 1.3 cm and the petioles measure up to 4.5 cm. Petiole growth is prostrate similar to *D.* 'Jaws Smiley'.

The name 'Purple People Eater' is a reference to the popular song by Sheb Wooley (1958) and is inspired by its stout, teeth-like cilia and purple coloration. Additionally, the acronym for 'Purple People Eater', PPE, is a reference to personal protective equipment which has become a common term in the COVID pandemic, during which plant selection was performed. 'EEC' is an acronym for Ev & Em Carnivorium where hand pollination and seed development was performed.

Dionaea 'EEC Purple People Eater' can only be propagated vegetatively by rhizome or leaf/floral cuttings to preserve the unique characteristics of the cultivar. *D.* 'EEC Purple People Eater' is currently grown only in Palo Alto, California and Lorton, Virginia.

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Figure 2: *Dionaea* 'EEC Purple People Eater'.

Dionaea 'Magikarp'

Submitted: 22 January 2021

Dionaea 'Magikarp' (Fig. 3) was selected in 2018 from a batch of offspring sown in 2016. The parents are all red-leafed clones. *Dionaea* "Magikarp' has short jagged teeth. The teeth are roughly triangular, but irregular, and often forked, one tooth is like rising layers of mountain peaks (or like the shape of Chinese character 山 which means mountain). Compared to other short-tooth flytraps, its teeth are more fragmented and irregular than *D.* 'Dentate' or *D.* 'Dracula', yet wider and neater than *D.* 'Bristle Tooth'. In abundant sunshine and cool temperature, it develops an extraordinary red trap interior with striking contrasting yellow-green trap margin. If the light is strong enough, especially in winter, the leaf margin will also take on a chestnut color. In terms of growth, *D.* 'Magikarp' is a vigorous grower, produces larger traps than average, and the leaves remain low to the ground year-round even in the summer.

In the sunshine, it shows beautiful red coloration on the interior of traps and yellow-green short teeth, just like the dorsal fin of Magikarp (Koi King) in Pokemon. And it always lies on the ground, like Magikarp on land.

The cultivar needs to be propagated by vegetive means to keep the unique character of the clone.

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Figure 3: *Dionaea* 'Magikarp'.

Drosera 'Avaricious Arugula'

Submitted: 23 February 2021

Drosera 'Avaricious Arugula' (Fig. 4) is a seed-grown plant from a small batch of seeds pollinated in early Spring of 2020. The seed plant of *Drosera* 'Avaricious Arugula' is a self-cross of the famous *Drosera* 'Hercules', and the pollen plant was a specimen of *Drosera capensis* from Bainskloof Pass, South Africa, making its genotype (*D.* 'Hercules' × Self) × *D. capensis*. The seeds of this cross were soaked in 0.01M hydroxylamine for three hours prior to being sowed on standard peat/perlite media.

Drosera 'Avaricious Arugula' is very vigorous and this specimen in particular grew to full size within six months, given weekly misting of MaxSea 16-16-16 fertilizer at 25% strength. The laminae of this plant are very thin and curly, even in high light conditions, and the entire surface of the leaf, both lamina and trap, is very wavy and almost ruffled at certain points. The width of the traps can exceed 1.5 cm and the laminae can measure up to 1 cm across. The plant is also anthocyanin free and largely glabrous. Another interesting tendency is that this plant forms many more aerial roots than any other of my specimens and cultivars of *D. capensis*, often holding between 4 and 6. Despite being in favorable conditions and growing rapidly, all of the flower spikes that this cultivar produces have been aborted, signifying that this cultivar is unable to flower.

My largest specimen has caught the most insects out of all of my *Drosera*, retaining the carcasses until I remove them with forceps. This character inspired the word "Avaricious" in this cultivar's name. The cultivar also reminded me of Arugula (*Eruca vesicaria* subsp. *sativa*) plants, with the warped leaves, hence the complete name of *Drosera* 'Avaricious Arugula'.

Since this plant does not produce viable flowers, vegetative propagation is required. I find the long roots *Drosera* 'Avaricious Arugula' produces strike easily and produce large plants in a matter of months. This cultivar also divides quite quickly, but due to the thin leaves, leaf cuttings often rot before they strike. Keeping specimens of this plant sitting in water is amenable because of how thin the leaves are, and specimens tend to grow faster in high-light, very humid environments. Despite this, they often succumb to root-rot so I advise a 2:3 peat:perlite mix. Specimens of *Drosera* 'Avaricious Arugula' have already been distributed to several growers and I plan on selling this cultivar in the coming fall.

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Figure 4: *Drosera* 'Avaricious Arugula'.

Sarracenia ‘Talisman’

Submitted: 12 December 2020

Sarracenia ‘Talisman’ (Fig. 5) is a spectacular plant that I grew from seeds many years ago. This is a complex cross with *S.* ’Reptilian Rose’, *S. flava*, and *S. leucophylla*.

The plant produces nice pitchers in spring and a second time at the end of summer. Pitchers are about 70 cm tall. Colours are green, purple, black with many fenestrations and veins on the higher part of pitchers. With time, the pitchers turn more purple and with dark colors, lips are black.

I named this plant *Sarracenia* ‘Talisman’ in reference to a precious and magic plant.

Sarracenia ‘Talisman’ must be reproduced vegetatively to preserve the unique characteristics of this cultivar.

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Figure 5: *Sarracenia* ‘Talisman’.

Drosera gibsonii

Drosera micrantha

Drosera leucostigma